METHOD AND APPARATUS FOR SELECTIVELY APPLYING INTERFERENCE CANCELLATION IN SPREAD SPECTRUM SYSTEMS

CROSS-REFERENCED TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application No. 60/412,550, entitled "Controller For Interference Cancellation and Spread Spectrum Systems," filed September 23, 2002, the entire disclosure of which is hereby incorporated by reference.

FIELD OF THE INVENTION

The present invention is directed to the application of interference cancellation in spread spectrum systems. In particular, the present invention is directed to selectively applying interference cancellation such that if interference cancellation has resulted in an improved signal, interference cancellation can be used or continued .

BACKGROUND OF THE INVENTION

Wireless communication systems should provide for a large number of secure (or private) communication channels within their allotted frequency space. In order to achieve these goals, spread spectrum systems have been developed. In a spread spectrum type system, spreading codes are used that allow multiple channels to occupy the same frequency range. In order to successfully demodulate a channel, the spreading code used in connection with the channel must be known. When a demodulation processor is tracking a particular signal path, signal paths associated with other transmitters appear to that processor as noise.

In order to provide for reliable communications, spread spectrum systems typically track multiple signal paths in connection with establishing and maintaining a

communication channel between a pair of end points. The different signal paths may result from redundant signals that are provided by additional base stations and base station sectors, or from reflected or multi-path versions of signals. In a typical receiver, a number (e.g. 4 to 6) demodulation processors or fingers are provided, and each of these fingers is assigned to track a different signal path. In order to obtain information regarding the different signal paths that are available to a receiver, a searcher demodulation processor or finger is provided. In a typical receiver, the searcher finger detects and identifies signals by pseudorandom number (PN) code offsets and signal strength. Because signal paths other than the signal path being tracked appear as noise to a demodulation processor, the signal to noise ratio with respect to a tracked or desired signal path can be low, which can result in a communication channel with poor quality and reliability. In particular, signals from sources that are in close proximity to the receiver can drown out signals from sources that are farther away from the receiver. Accordingly, because of this "near-far" problem, signal diversity is limited. In addition to leaving communication channels more vulnerable to interruption, relatively weak signals that might otherwise be available to a receiver lie beneath the noise floor created in the environment by other relatively strong signals. This limitation in acquiring and tracking signals from distant sources caused by the near-far problem also limits the effectiveness of location schemes that rely on triangulation techniques.

In order to address the near-far problem, schemes have been developed for controlling the power of signals produced by sources, e.g. beam steering and smart antenna application. However, such schemes may be complex and difficult to implement. In addition, where sources such as base stations are in communication with a large number of receivers, some of which are close to the source and others of which are far from the source, the limitation of signal power may not be feasible.

Another approach to allowing receivers to effectively track signals subject to near-far interference has been to apply interference cancellation. Such systems remove

signal paths that are extraneous from the signal path being tracked in a demodulation finger. However, such systems have not provided for the flexible application of such cancellation. As a result, the use of conventional interference cancellation schemes, as they have heretofore been applied, can actually result in poorer signal to noise ratios with respect to desired signal paths than if no interference cancellation had been applied.

SUMMARY OF THE INVENTION

The present invention is directed to solving these and other problems and disadvantages of the prior art. According to the present invention, a method and apparatus for selectively applying interference cancellation to signals is provided. For example, the present invention may apply interference cancellation only if such cancellation results in an improvement in the strength of desired signal paths. Embodiments of the present invention also allow for the selection of an interference cancellation scheme that is determined to be preferred over other interference cancellation schemes or over an arrangement in which only non-interference cancelled signals are provided to demodulation processors or fingers.

According to embodiments of the present invention, the strength of each of a number of signal paths or identified signals at a receiver is determined, and one or more signal paths that are stronger than other signal paths are identified or determined to contribute a greater amount of interference. According to further embodiments of the present invention, signal paths that are not necessarily the strongest but that negatively affect another signal path are identified. Cancellation of signal paths identified as having a high strength or that negatively affect another signal path or paths from signal streams (i.e. raw or interference cancelled received streams) within a receiver may be initiated by providing an estimate of a signal path being considered for cancellation to a signal cancellation module. An estimate of the signal path may be prepared by a channel determination module for the signal cancellation module. The signal cancellation module

removes the estimate of the strong potentially interfering signal path from another signal stream or signal streams (i.e., from one or more signal streams that may be provided to demodulation fingers assigned to track signal paths other than the signal path being cancelled). The cancellation controller then determines whether the signal to noise ratio of the signal path or paths derived from the signal stream or streams from which the potential interferer have been removed have increased. If an increase in the signal to noise ratio of a desired signal path is detected, the potential interferer is identified as an actual interferer, and the interference canceled version of the desired signal stream may be provided to the demodulation finger assigned to that desired signal path.

If an increase in the signal to noise ratio of a desired signal path is not detected, the interference canceled signal stream will not be provided to a demodulation finger assigned to that desired signal path. In accordance with another embodiment of the present invention, an interference canceled signal stream is not provided to a demodulation finger assigned to a desired signal path unless it has been determined that the interference canceled signal stream will likely result in an increase in the strength of the desired signal by at least a threshold amount. In accordance with embodiments of the present invention, the analysis of the effect of providing different interference canceled signals to demodulation fingers can proceed such that either the raw signal stream or an interference canceled signal stream is identified as providing the greatest signal strength with respect to a desired signal path. This can be done for each signal path assigned to a demodulating finger provided by a receiver. In accordance with another embodiment of the present invention, signal cancellation may be achieved using various methods. For example, a replica of the potential interferer or identified interferer may be subtracted from the raw signal stream. In accordance with another embodiment of the present invention, serial cancellation techniques using projection-based methods of removing potential interferers or identified interferers may be used. In accordance with still other

embodiments of the present invention, parallel cancellation of potential interferers and identified interferers may be applied.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram depicting components of a spread spectrum receiver in accordance with the prior art;

Fig. 2 is a block diagram of components of a spread spectrum receiver in accordance with an embodiment of the present invention;

Fig. 3 is a diagram depicting the flow of signals through a spread spectrum receiver in accordance with an embodiment of the present invention;

Fig. 4 is a schematic depiction of signal and information flows through a spread spectrum receiver in accordance with an embodiment of the present invention;

Fig. 5 is a flowchart illustrating aspects of a controller operating cycle in accordance with an embodiment of the present invention;

Fig. 6 is a flowchart illustrating aspects of the operation of a spread spectrum receiver in accordance with an embodiment of the present invention;

Fig. 7 is a flowchart illustrating a process for updating a to cancel list in accordance with an embodiment of the present invention;

Fig. 8 is a flowchart illustrating a process for adding signal paths to a to cancel list in accordance with an embodiment of the present invention;

Fig. 9 is a flowchart illustrating a process for updating a survey path list in accordance with an embodiment of the present invention;

Fig. 10 is a flowchart illustrating a process for removing a path from a to cancel list in accordance with an embodiment of the present invention;

Fig. 11 is a flowchart illustrating a process for controlling the signal flow to a demodulation finger in accordance with an embodiment of the present invention;

Fig. 12 illustrates the contents of a candidate to cancel list in accordance with an embodiment of the present invention;

Fig. 13 illustrates the contents of a to cancel list in accordance with an embodiment of the present invention;

Fig. 14 illustrates the contents of a canceled paths list in accordance with an embodiment of the present invention; and

Fig. 15 illustrates the contents of a canceled signal feed list in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION

With reference now to **Fig. 1**, components of a baseline or prior art spread spectrum communication receiver 100 are illustrated. As depicted in **Fig. 1**, signals are provided to a radio frequency front end 104 by an antenna 108. In a typical environment, a number of different signals, for example, signals produced by different base stations, different sectors of a base station, or multi-path or reflected versions of the signals can be received at the radio frequency front end 104. As can be appreciated by one of skill in the art, signals from different base stations or different sectors of a base station are typically identified by an associated path number, which identifies the base station or base station and sector according to the time offset of the signal path. Multi-path versions of signals are identified by the path number of the line of sight version of the signal, plus an additional time offset to account for the longer path followed by the reflected signal. As can further be appreciated by one of skill in the art, signal paths from different sources are typically separated by a distance (e.g., 64 chips) sufficient to allow the source of multi-path versions of signal paths to be correctly identified with the source of such signal paths.

The raw signal stream 112 collected by the receiver 100 and down-converted by the RF front end 104 is provided to a searcher finger 116. The searcher finger functions

to scan the signal stream 112 for individually identifiable signal paths and/or multi-paths. In particular, the searcher finger 116 operates to determine the path number or pseudorandom number (PN) code offset associated with each identifiable signal path. As noted above, the PN code identifies this signal path as being associated with a particular base station or base station sector. In code division multiple access (CDMA) systems, the PN code sequence is referred to as the short code.

The searcher finger 116 reports the signal paths that have been identified to the controller 120. Information provided to the controller may be placed in a survey path list. In general, the survey path list identifies by PN offsets those signal paths that are visible to the searcher finger 116. Alternatively, the survey path list may contain the PN offsets for those signal paths that have at least a threshold signal to noise ratio or strength.

The controller 120 reports the identities of the signal paths to the survey path list. From the survey path list, the controller 120 may decide to acquire and track one or more of the signal paths on the survey path list. In general, the number of signal paths that a receiver 100 can be directed to track is limited by the number of demodulation fingers 124 provided as part of the receiver 100. The signal paths assigned to the receiver 100 for demodulation and tracking may be provided as a demodulation path list. In a typical communication system, the demodulation path list comprises an identifier for each demodulation finger 124, an identifier of the signal path assigned to each demodulation finger 124, any additional time offset, the observed strength of the signal and the sector of the signal path.

The demodulation fingers 124 receive as a feed signal the raw signal stream 112 from the radio frequency front end 104, and each acquires the signal path assigned to that finger 124, as set forth in the demodulation path list. The demodulated signal stream is then provided to a symbol combiner 132, which combines the demodulated signal streams 128 provided by the demodulation fingers 124. For example, the signal combiner 132 and the demodulation fingers 124 collectively comprise a rake receiver.

Although the receiver 100 depicted in **Fig. 1** illustrates first 124a and second 124b demodulation fingers, and associated first 128a and second 128b demodulated signals, receivers 100 having varying numbers of demodulation fingers 124 have been developed. For example, commercially available CDMA telephones commonly have from 4 to 6 demodulation fingers 124.

The prior art receiver 100 illustrated in **Fig. 1** does not include an interference canceller for providing an interference canceled signal stream to the demodulation fingers 124. Receivers 100 that provide signal cancellation have been developed. However, such systems have not provided for selective application of interference cancellation. Accordingly, such systems have applied signal cancellation without regard to whether such cancellation actually results in improvements to the signal strengths of desired signal paths. Accordingly, such systems can actually reduce the observed signal strength of desired signal paths.

With reference now to **Fig. 2**, a cancellation controlled receiver 200 in accordance with an embodiment of the present invention is illustrated. In general, the receiver 200 provides for the selective application of interference cancellation. For example, a receiver 200 in accordance with the present invention is capable of determining whether an interference canceled signal stream will improve the observed strength of a desired signal path in the receiver 200. Furthermore, such a determination can be made before an interference canceled signal stream is provided to a demodulation finger. In addition, the receiver 200 can provide a different interference canceled signal stream, or a signal stream that has not undergone interference cancellation, if it is determined that a previously selected interference canceled signal stream is no longer resulting in an improved signal to noise ratio with respect to a desired signal path.

In general, the receiver 200 includes a radio frequency (RF) front end 204 and associated antenna 208. The raw signal stream 212 collected by the RF front end 204 and antenna 208 is provided to a searcher finger 216. The searcher finger 216 may operate to

locate signals within the raw signal stream 212. The identity of the signal paths located by the searcher finger may then be reported to a baseline controller 220. In particular, information regarding signal paths located by the searcher finger 216 may be used to construct a survey path list. The baseline controller 220 assigns the receiver 200 to track all or a selected set of the signal paths identified in the survey path list. The assignment of signal paths that are to be acquired and tracked by demodulation fingers 224 in the receiver 200 may be performed in association with a demodulation path list. In **Fig. 2**, only two demodulation fingers 224a and 224b are shown. However, it should be appreciated that any number of additional demodulation fingers 224 may be provided.

As shown in **Fig. 2**, the baseline controller 220 may be in communication with a cancellation controller 228. The cancellation controller 228 is unique to the present invention. In general, and as will be described in greater detail elsewhere herein, the cancellation controller 228 controls the production and selection of interference canceled signals. As part of the selection process, the cancellation controller 228 is capable of determining that interference canceled signal streams available to the receiver 200 do not result in improving the signal to noise ratio of a desired signal path, and may therefore direct the provision of the raw signal stream 212 as a feed signal stream to all or some of the demodulation fingers 224.

As shown in **Fig. 2**, the cancellation controller 228 may include one or more channel determination modules 232 and one or more signal cancellation modules 236. In general, the channel determination modules 232 operate to produce replicas of signal paths that are identified by the cancellation controller 228 as being potential or actual interferer signal paths. The signal cancellation modules 236 receive the replica signal paths, and perform cancellation to remove such signals from the raw signal stream 212. The cancellation controller may also include one or more correlators 238 for determining whether interference canceled signal streams produced in the signal cancellation modules 236 provide a desired signal path having an increased strength.

In order to provide either the raw (or baseline) signal stream or an interference canceled signal stream to a demodulation finger 224, a signal line 244a and 244b for carrying the signal stream is provided between the cancellation controller 228 and the corresponding demodulation fingers 224a and 224b. In addition, control signal paths 240 are provided between the cancellation controller and the demodulation fingers 224 to control the delay or advance of the PN codes by the PN generator 246 associated with each demodulation finger 224. The ability to delay or advance the PN generators 246 associated with the demodulation fingers 224 is advantageous because it allows the demodulation fingers 224 to each track a provided feed signal stream 244, even if that feed signal stream 244 has undergone delays, for example in processing in the cancellation controller 228. The cancellation controller 228 may also provide a demodulated signal delay control signal 248 to a delay buffer 252 to control an amount of delay introduced by each demodulation finger 224 before a symbol obtained from the provided signal stream 244 is made available to a symbol combiner 260. By so controlling the delay within the demodulation fingers 224, demodulated signal streams 256 can be synchronized by the cancellation controller 228. Accordingly, a conventional symbol combiner 260 may be used. Alternatively, a symbol combiner 260 that is capable of synchronizing symbols obtained from the processing of signal streams 244 by the demodulation fingers 224 may be used, in which case the delay buffers 252 and associated signal lines could be omitted. As yet another alternative, the cancellation controller 228 may provide feed signal streams to demodulating fingers 224 after a fixed delay with respect to the raw signal stream 212 as it is received in the RF front end 204 so a conventional combiner 260 may be used.

In accordance with an embodiment of the present invention, the receiver 200 may also provide an interference canceled signal connection 264 capable of delivering an interference canceled signal stream from the cancellation controller 228 to the searcher finger 216. Such an embodiment allows the searcher finger 216 to scan interference

canceled versions of the raw signal stream 212 for available signal paths. Accordingly, signal paths that may have been buried beneath the noise floor in a raw signal stream 212 may become visible to the searcher finger 216 in an interference canceled signal stream. Accordingly, a greater number of signal paths can be made available to the receiver 200 for acquisition and tracking by the provided demodulation fingers 224, which can increase the reliability and quality of a communication channel. In addition, by potentially making signal paths originating at additional base stations visible to the receiver 200, location technologies that utilize triangulation techniques between different signal sources and the receiver 200 can provide a more accurate location determination.

In connection with an embodiment in which the searcher finger 216 may be directed to scan interference canceled signal streams, the cancellation controller 228 may operate to provide PN code delay information to the searcher finger 216. Such information allows the searcher finger 216 to accurately identify the PN of signal paths, even though the feed signal streams will have been delayed by the process of creating the interference canceled signal stream.

With reference now to **Fig. 3**, signal flows within a receiver 200 in accordance with an embodiment of the present invention are illustrated. As shown in **Fig. 3**, the flow of signal streams through the receiver 200 begins with the receipt of the raw data signal stream 212. The raw signal stream is provided to the searcher finger 216, and also to the demodulation fingers 224. The demodulation fingers 224 each produce a demodulated signal stream 304. In **Fig. 3**, three demodulated signal streams 304a, 304b and 304n are depicted. Accordingly, **Fig. 3** would correspond to a receiver 200 having at least three demodulation fingers 224. As can be appreciated by one of skill in the art, the depiction of three demodulated signal streams 304 is representative. In particular, a receiver 200 may produce a greater or lesser number of demodulated signal streams, provided that an appropriate number of demodulation fingers 224 are available.

The demodulated signal streams 304 are provided to the channel determination modules 232 of the cancellation controller 228. As will be described in greater detail elsewhere herein, the channel determination modules 232 produce estimates of potential interfering signals 308. In **Fig. 3**, estimates 308a, 308b and 308n are shown. Accordingly, an embodiment producing the data flow illustrated in **Fig. 3** might have three channel determination modules 232. However, it should be appreciated that the number of channel determination modules 232 is not required to match the number of demodulation fingers 224 provided by a receiver 200.

The estimates of potential interfering signal paths 308 are provided to the signal cancellation modules 236 of the cancellation controller 228. The signal cancellation modules remove the interfering signal paths from one or more of the feed signal streams provided to the demodulation fingers 224. For example, the estimate 308a of the first demodulated signal path 304a may be removed from the signal stream that will be provided to the demodulation finger 224 assigned to track the second signal path and/or the demodulation finger 224 assigned to track the n^{th} signal path. The estimate of the n^{th} signal path may also be removed from either or both of the feed signal streams provided to the demodulation fingers 224 assigned to track the first and second desired signal paths. Likewise, the estimate of the second interfering signal path 308b may be removed from either or both of the signal streams provided to the demodulating fingers 224 assigned to track the first and n^{th} signals path. The cancellation controller 228 then checks the strength of the interference canceled signal path 312a-n for the assigned signal paths. If it is determined that the strength, for example as represented by an observed signal to noise ratio, has increased for an interference canceled signal path, that interference canceled signal stream may be provided to the assigned demodulation finger. If it is determined that the strength of a desired signal path has not been increased through the use of an interference canceled feed signal stream, the interference canceled signal stream 312 under consideration is not sent to the demodulating finger 224 assigned to

track the signal path under consideration. Instead, another signal stream, such as the raw signal stream 212, or a previous version of an interference canceled signal stream 312 having a different signal or set of signals cancelled therefrom, may be provided as the feed signal stream to the demodulating finger 224.

With reference now to **Fig. 4**, the flow of signal streams through a receiver 200 in accordance with an embodiment of the present invention, showing the use of various lists or tables and their relationship to functional elements, is illustrated. Initially, a raw signal stream 212 is provided as a feed signal stream to the searcher finger 216. The searcher finger scans the raw data signal stream 212 to locate and identify signal paths available to the receiver 200. As shown in **Fig. 4**, an interference canceled signal stream 264 may, in accordance with some embodiments of the present invention, be provided in addition or as an alternative to the raw data signal stream 212. As noted above, the searcher finger 216 provides the information identifying the available signal paths to the baseline controller 220. The baseline controller 220 uses the information provided by the searcher finger 216 to prepare a survey path list 404. The survey path list generally includes the PN offsets of signals located by the searcher finger 216. The baseline controller 220 uses the information from the survey path list to assign signal paths to be tracked by the receiver 200 in available fingers. These assignments are recorded in the demodulation path list 412. Accordingly, the demodulation path list 412 may identify the fingers available in the receiver 200, the signal path assigned to each finger, any time offset, the signal strength of each signal path, and the sector of the signal path. The demodulation path list 412 is then made available to the cancellation controller 228.

The cancellation controller 228 checks for the presence of interfering signal paths in the demodulation path list 412. For example, in accordance with an embodiment of the present invention, the cancellation controller 228 may check for signal paths being tracked by a demodulation finger 224, and that therefore are listed in the demodulation path list 412, that have a signal strength that is greater than a predetermined threshold.

The strength of the signal paths may be determined by measuring the signal to noise ratio of the signal path, or a selected component or channel of the signal path. For example, in accordance with an embodiment of the present invention, the strength of the pilot channel signal transmitted by a base station may be measured to determine the strength of the signal paths. In accordance with another embodiment of the present invention, some or all of the traffic channels, the pilot channel, the paging channel, and/or the synchronization channel may be used to determine the strength of a signal path. As can be appreciated by one of skill in the art, greater accuracy in measuring the strength of a signal path can be realized if all or a significant number of the channels or signals within a signal path are measured. However, monitoring a large number of the channels and/or signals within a signal path is computationally expensive. Accordingly, embodiments of the present invention can monitor a relatively small number of the channels or signals within a signal path. For instance, the strength of the pilot signal alone may be measured to determine the strength of the associated signal path. For example, estimates of signal strengths can be determined from the E_c/I_o, where E_c is energy per chip and I_o is the total power or interference in the system, can be used to provide a signal to noise ratio value for estimating the strength of the signal path.

Signal paths meeting the criteria for a potential interfering signal path are identified in a candidate to cancel list or table 416. With reference now to **Fig. 12**, the elements of an exemplary candidate to cancel list 416 are illustrated. As shown in **Fig. 12**, the candidate to cancel list 416 may include entries identifying demodulating fingers 224, the signal paths 1204 assigned to each demodulating finger 224, the signal strength 1208 of the signal path, and the sector 1212 of the signal path. As can be appreciated by one of skill in the art, each signal path may comprise or reference a different PN code offset or multipath version of a PN code offset.

The strongest signal paths included in the candidate to cancel list 416 are assigned to a to cancel list or table 420. As illustrated in **Fig. 13**, in accordance with an

embodiment of the present invention, the to cancel list 420 contains a maximum of n signal paths, where n corresponds to the number of channel determination modules 232 provided by the cancellation controller 228. Accordingly, where the number of potential interfering signal paths exceeds the number of channel determination modules 232, the to cancel list 416 may include the n strongest potential interfering signal paths. With reference now to **Fig. 13,** the contents of a to cancel list in accordance with an embodiment of the present invention is illustrated. In general, the to cancel list 420 includes an entry for a demodulating finger 224 and a corresponding signal path 1304. In particular, the to cancel list 420 identifies signal paths that are to be canceled.

With continued reference to **Fig. 4,** using the information included in the to cancel list 420, the cancellation controller 228 operates the channel determination modules 232 to provide outputs from one or more of the demodulation fingers 224 to the appropriate channel determination module or modules 232. Optionally, the information regarding the pairings of the output from demodulation fingers 224 to channel determination modules 232 may be maintained in a channel determination list or table 424, which generally contains the same information as the to cancel list 420. By providing the appropriate signal streams to the channel determination modules 232, interference canceled signal streams are available at the output of the signal cancellation modules 236. The cancellation controller 228 may further implement or control multiplexers 428 for selecting an output available from a signal cancellation module 236 or a raw signal stream 212 to be provided in the receiver 200 as a feed signal stream to a demodulation finger 224 or to a correlator 238 provided as part of the cancellation controller 228. The cancellation controller 228 then determines whether the interference canceled signal streams provided to some or all of the demodulation fingers 224 or correlators 238 has resulted in an improved desired signal strength. In accordance with an embodiment of the present invention, this determination is made by correlating desired signal paths with the raw signal stream 212 and the interference canceled signal stream provided to the

corresponding demodulation finger 224. The correlator implemented by the cancellation controller 228 may further comprise a bank of correlators 238.

In accordance with an embodiment of the present invention, a correlator 238 operates by performing a vector inner product or correlation operation: $x^T y$, where x is a reference signal, such as a pilot signal, ^{T} is the transpose operation, and y is a feed signal stream. Therefore, whether the use of an interference cancelled signal y_1 results in an improved signal strength can be determined comparing the result of $x^T y_1$ to the result of $x^T y_{raw}$, where y_{raw} is a non-interference cancelled signal stream,. The reference signal x, may consists of nothing but a series of 1's and -1's,e.g. the short code or PN sequence. This reference signal may consist of a replica of the pilot channel, which is a non-information bearing channel. The result of the vector inner product can then be used to determine the strength of the correlation between the received signal stream and the PN sequence, because the PN sequence is known. As still another example, signal cancellation could be performed with respect to an interference cancelled version of x and y_{raw}. In accordance with still another embodiment of the present invention, a look-up table can be used in place of a correlation operation. In particular, using information regarding the relative signal to noise ratios of a raw signal path and an interference cancelled signal path, previously calculated values stored in a look-up table can be referenced in order to estimate whether it would be preferable to use an interference cancelled signal stream or a non-interference cancelled signal stream.

Those signal paths, the cancellation of which resulted in improved signal strengths for a desired signal path, are listed in a canceled paths list or table 432 (**Fig. 4**). **Fig. 14** illustrates the contents of a canceled paths list 432 in accordance with an embodiment of the present invention. As shown in **Fig. 14**, the canceled paths list 432 may indicate those signal paths that have been canceled from a signal stream provided to a demodulation finger 224. The canceled paths list 432 is then compared to the demodulation path list 412.

If a signal path is present on both the demodulation path list 412 and the canceled paths list 432, a canceled signal feed list or table 436 is updated to indicate that the feed to one or more demodulation fingers 224 comprises an interference canceled signal stream, rather than a raw signal stream. With reference now to **Fig. 15**, a canceled signal feed list 436 in accordance with an embodiment of the present invention is illustrated. As shown in **Fig. 15**, the canceled signal feed list may contain a list of demodulation fingers 224. For each demodulation finger 224 in the canceled signal feed list 436, the identity of a signal cancellation module 236 and canceled signal path 1504 may be indicated. If a demodulation finger 224 is not listed in the canceled signal feed list 436 as receiving an interference canceled signal stream, it is provided with the raw signal stream 212.

With reference now to **Fig. 5**, a channel determination cycle in accordance with an embodiment of the present invention is illustrated. Initially, at step 500, a demodulation path list 412 is created or modified. At step 504, the demodulation path list is read, and at step 508 the strong potential interferers are identified. Next, at step 512, interference canceled signal streams are created. In particular, signal streams from which one or more strong potential interfering signal paths have been removed are created.

At step 516, the interference canceled signal streams are correlated with the reference signal and the raw data signal 212 correlated with the reference signal is computed. A determination is then made as to whether the signal to noise ratio (i.e., the strength) of a desired signal at the output of a corresponding correlator 238 has improved (step 520). If the strength of the desired signal path has improved, the interference canceled version of the input signal stream is provided to the demodulation finger 224 for use in connection with communications involving the receiver 200 (step 524). If the strength of the signal path from the finger 224 has not improved, the interference canceled version of the signal stream is not provided to the finger 224. Instead, the raw signal stream is provided to the finger 224.

At step 528, a determination is made as to whether there are more signal streams to be considered. If signal streams remain to be considered, the next signal is obtained (step 532), and the system returns to step 520. In this way, the effect of providing an interference canceled signal stream to each demodulation finger 224 in a receiver 200 is assessed. If no more signal streams remain to be considered, the channel determination cycle ends (step 536). As can be appreciated by one of skill in the art, the channel determination cycle may start again the next time that the signal paths to be tracked by the demodulating fingers 224 change. For example, the channel determination cycle may start again when the demodulation path list 412 is created or modified.

With reference now to **Fig. 6**, the operation of a receiver 200 in accordance with an embodiment of the present invention is illustrated in greater detail. As shown in **Fig. 6**, at step 600 the demodulation path list, listing demodulating fingers 224 and the signal path assigned to each finger, is obtained. At step 604, the signal paths that are potential interferers are identified. For example, in accordance with an embodiment of the present invention, those signals paths having a signal strength that is greater than a predetermined threshold are identified. The identified potentially interfering signal paths are then stored in the candidate to cancel list 416 (step 608). From the candidate to cancel list, up to n signal paths are assigned to the to cancel list 420 (step 612).

At step 616, the output of each demodulation finger 224 is connected to a corresponding channel determination module 232, and estimates of the interfering signal paths are produced. In accordance with an embodiment of the present invention, the estimate of the interfering signal path comprises a replica of that signal path, where the signal cancellation implemented by the signal cancellation modules 236 uses subtractive cancellation. In accordance with another embodiment of the present invention, the estimate of an interfering signal path is expressed as a vector or matrix as described in U.S. Patent Application Serial No. 10/294,834, filed November 15, 2002, for use in a serial cancellation interference cancellation design, as described in U.S. Patent

Application Serial No. 10/247,836, filed September 20, 2002, the entire disclosure of which is incorporated herein by reference, or for use in a parallel type signal cancellation arrangement as described in U.S. Patent Application Serial No. 60/445,243, filed February 6, 2003, the entire disclosure of which is also incorporated herein by reference, where a non-orthogonal projection of an interfering signal path is made to cancel the interference. In accordance with another embodiment, in addition or as an alternative to such non-orthogonal projection techniques, orthogonal projection techniques may be used. In general, any suitable noise or signal cancellation technique can be used in connection with the selection process provided in connection with embodiments of the present invention. In accordance with an embodiment of the present invention, the replica of the interfering signal path is produced by monitoring one or more Walsh code channels present in the signal path to be canceled. Accordingly, a signal path identified as an interfering signal path, and therefore a signal path that is to be canceled from other signal streams, must be tracked within at least one of the demodulation fingers 224 in order to build a replica signal. Moreover, by tracking the signal path to be canceled in one of the fingers, correlation can be performed periodically to determine the power of that signal and the amount of interference that it contributes.

At step 620, the signal cancellation modules 236 remove the interfering signal path from a feed signal stream using the estimates from the channel determination modules 232. The cancellation controller 228 then checks the strength of the resulting signal paths, and adds signal paths having increased strength to the canceled paths list 432 (see **Fig. 4**). As can be appreciated by one of skill in the art, more than one interference canceled stream may provide a benefit to a signal path, in which case a choice must be made between more than one signal streams that provide a benefit. Such choice can be made by ranking the estimated effects of providing the various signal streams. Then, the survey path list 404 may be updated to reflect the new signal strength for the monitored signal paths. Accordingly, a number of different interference cancelled

signal streams and the raw signal stream may be evaluated with respect to the reception of one or more signal paths.

At step 628, a determination is made as to whether the demodulation path list 412 has been updated. If new paths have been assigned, the demodulation path list 412 is updated (step 632). If new paths have not been assigned to the demodulation path list, or after updating the demodulation path list 412, the canceled path list 432 and demodulation path list 412 are compared, and the appropriate interference canceled signal stream is sent to the corresponding finger 424 if that signal path is present on both lists (step 636). That is, if a signal path is present on both lists, it is being tracked by a demodulation finger 224, and thus an estimate of that signal path can be prepared, and it has been identified as an interfering signal path with respect to at least one other signal path being tracked within the receiver 200. The canceled signal feed list 436 (see Fig. 4) is then updated to indicate the assignment of interference canceled signal streams to demodulation fingers 224 (step 640).

With reference now to **Fig. 7**, a process for updating a to cancel list 420 in accordance with an embodiment of the present invention is illustrated. Initially, at step 700, the cancellation controller 228 initiates a check of the to cancel list 420. At step 704, a count value p is set equal to the first element (corresponding to a desired signal path) in the to cancel list 420. Next, a determination is made as to whether element p appears in the candidate to cancel list 416 (step 708).

If p appears in the candidate to cancel list 416, the signal strength for path p in the to cancel list 420 is updated, and element p is removed from the candidate to cancel list 416 (step 712). A determination is then made as to whether there are more paths in the to cancel list 420 to be considered (step 716). If there are other paths in the to cancel list 416, p is set equal to the next element in the to cancel list 416 (step 720). If there are no additional paths in the to cancel list 416, the process of updating the cancel list 416 ends (step 724).

If at step 708 it is determined that p is not in the candidate to cancel list 416, path p is removed from the to cancel list 420 (step 728). Channel determination is initiated, and cancellation of path p is disabled (step 732). The process then proceeds to step 716 to determine whether there are more paths in the to cancel list 420 to consider.

With reference now to **Fig. 8**, a process for adding signal paths to a to cancel list 420 in accordance with an embodiment of the present invention is illustrated. Initially, at step 800, p is set equal to the first path in the candidate to cancel list 416. At step 804, path p is added to the to cancel list 420. An update of channel determination is then performed, and appropriate connections to channel determination modules are enabled (step 808). At step 812, a determination is made as to whether there are additional paths in the candidate to cancel list 416. If there are additional paths, p is set equal to the next element in the candidate to cancel list 416 (step 816) and the process returns to step 804. If there are no additional paths in the candidate to cancel list 416, the process may proceed to update the survey path list 404 (step 820).

With reference now to **Fig. 9**, a process for updating a survey path and/or cancel path list in accordance with an embodiment of the present invention is illustrated. In general, this process is entered while the to cancel list 420 is not null (i.e., while there are signals listed for cancellation) (step 900). At step 904, s(i) is set equal to the first element in the to cancel list 420. The searcher finger 216 is then commanded to check the interference canceled signal (i) for the strengths of all PN offsets in the survey paths (step 908). Alternatively, the interference cancelled signal is sent to a bank of correlators 238. The survey path list 404 is then updated for any PN offsets that show a signal to noise ratio improvement greater than some threshold amount (step 912). In accordance with an embodiment of the present invention, the survey path list 404 maybe updated for any PN offsets that show any improvement. It should be appreciated that updating the survey path is optional. In particular, the survey path list may be updated if an interference canceled signal stream is sent to the searcher or by some other means. However,

updating the survey path list is not necessary in other circumstances for a cancellation controller in accordance with embodiments of the present invention to work.

At step 916, any updated paths are added to the canceled path list 432. Such paths are then removed from any previous canceled path (i-1) list (step 920). A determination is then made as to whether there are additional elements in the to cancel list 420. If elements remain in the to cancel list 420, s(i) is set equal to the next element in the to cancel list 420, and the process returns to step 908. If there are no more elements in the to cancel list 420, the process for updating the survey path list 404 ends (step 932).

With reference now to **Fig. 10**, a process for removing a path from a to cancel list 420 in accordance with an embodiment of the present invention is illustrated. Initially, at step 1000, the cancellation controller 238 generates a signal to de-assign element p from the to cancel list 420. Thus, at step 1004, the corresponding entry in the to cancel list 420 is nulled. The flow of data from the finger 224 tracking the signal associated with element p to the channel determination module 232 is disconnected and the state of the channel determination module 232 is reset (step 1008). The corresponding signal cancellation module 236 is disabled and is also reset (step 1012). At step 1016, the PN codes in the demodulation fingers 224 are then advanced or slewed accordingly in order to synchronize with the baseline or raw signal 212. The process for removing a path from the to cancel list then ends (step 1020).

With reference now to **Fig. 11**, a process for controlling the signal flow to a demodulation finger in accordance with an embodiment of the present invention is illustrated. Initially, at step 1104, the cancellation controller 228 signals that signal path p is to be added to the canceled signal feed list (i) 436. At step 1108, the demodulating finger 224 for path p is determined. At step 1112, a signal stream from which signal path p has been canceled is provided to the finger assigned to receive that interference cancelled signal stream (as shown in the canceled signal feed list 436). The PN generator in the demodulating finger 224 associated with the canceled signal feed list 436

is then delayed or slewed to synchronize with the interference canceled signal stream now being provided (step 1116). The process for controlling the signal flow to a demodulation finger then ends (step 1120).

As can be appreciated by one of skill in the art, the present invention provides a method and apparatus for selectively applying interference cancellation. In particular, the present invention allows either the provision of an interference cancelled signal stream or a non-interference cancelled signal stream to a demodulation finger, in order to provide the most favorable signal to noise ratio. It should further be appreciated that the present invention can be used in connection with any existing or newly developed signal cancellation procedure or mechanism to selectively apply such signal cancellation. In particular, by considering the effect or estimated effect of different signal streams on the reception of a desired signal path, the raw or interference cancelled signal streams providing a more favorable reception of a desired signal path can be selected. In particular, by allowing interference cancelled signal streams to be selectively applied, the present invention can avoid obtaining a degraded signal to noise ratio for a desired signal path as a result of the blind application of an interference cancelled signal stream. Specifically, the present invention provides a method and apparatus by which a preferred feed signal stream can be identified and provided to a demodulating finger.

Although the description provided herein has at times used examples of receivers comprising cellular telephones in spread spectrum systems, it should be appreciated that the present invention is not so limited. In particular, the present invention may be applied to any wireless communication system component implementing a wireless link or channel capable of using a plurality of channels substantially simultaneously. Accordingly, the present invention may be used in both mobile devices, such as telephones or other communication endpoints, or in wireless base stations or nodes. Furthermore, the present invention is not limited to terrestrial applications. For example, the present invention may be used in connection with satellite communication systems.

In addition, the present invention is not limited to voice communication systems. For example, embodiments of the present invention may be applied to any multiple channel system, including radio locating systems, such as the global positioning system (GPS), multi-media communications, and data transmission systems.

The foregoing discussion of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, within the skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments described hereinabove are further intended to explain the best mode presently known of practicing the invention and to enable others skilled in the art to utilize the invention in such or in other embodiments and with various modifications required by their particular application or use of the invention. It is intended that the appended claims be construed to include the alternative embodiments to the extent permitted by the prior art.